§5. Design Study of Indirect Cooling Superconducting Magnet for the Helical Reactor

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The design study of the superconducting magnet for the helical reactor has been started considering the condition of continues helical winding, steady state operation without pulse magnetic field change and plasma disruption in a Tokamak reactor. The design of the superconducting magnet for a helical reactor has been facilitated because there is no magnetic field change to induce the plasma current, and there is no rapid change such as plasma disruption. However, the conventional forced-flow cooled magnet with CICC may not be applicable for a helical reactor because the conductor length of the continuous helical winding becomes too long and the pressure drop becomes too much. Then, we are examining the introduction of the indirect cooling method as one example of a new superconducting coil structure to make the best use of the feature of a helical reactor.

The concept design of the conductor for the indirect cooling method is shown in Fig. 1 and the coil structure is shown in Fig. 2. The transposed conductor composed of several compacted strand cables, where the increase of AC losses caused by the non-uniform cabling, etc. doesn't occur, is assumed as a basic structure of the conductor. The A15 inter-metallic compound superconductor such as Nb_3Sn or Nb_3Al is used so that a maximum magnetic field of 13 T – 15 T is applied to the conductor in the windings. The conductor achieves coexisting of a mechanical strength and the heat conduction characteristic for the indirect cooling by covering the superconducting conductor with the aluminum alloy. After the heat treatment, the superconducting conductor is covered with the aluminum alloy because the melting point of the aluminum alloy is close to the temperature of the heat treatment of superconductor. Therefore, it becomes React & Wind as a fabrication sequence of the superconducting magnet. The winding work is done by burying the above-mentioned conductor insulated with the ceramic coating etc. on the electromagnetic force supporting plate where the ditch was processed to the shape of the conductor. In the windings, the cooling panels are inserted in every winding block of a few layers and it is cooled indirectly. The cooling panel has the internal cooling passes and is cooled by circulating the supercritical helium etc.

The magnet design with high degree of freedom is enabled by separating the cooling passing and the current passing with the indirect cooling concept. Becoming the problem by the indirect cooling method is whether nuclear heat generation in the superconducting magnet is removed enough, and the temperature rise in the windings can be suppressed. The nuclear heating in the magnet is lower than about 100 W/m^3, and assuming the thickness of a winding block to be 0.1m and if 10W/m^2 can be achieved as heat removal ability of the cooling panel, the magnet can be cooled enough. The temperature rise in the windings by nuclear heat generation becomes 0.25 K or less if it is assumed 4 W/mK (corresponding to the heat conduction of aluminum alloy) as thermal conductivity of the winding. It is possible to suppress the maximum temperature in the winding to 1 K or less even if it is considered that the thermal conductivity in the electric insulation layer is low. From the above-mentioned outline examination, the application possibility of the indirect cooling method to a helical reactor was shown. The development of the large current capacity conductor, the insulation structure that can be used in the neutron irradiation environment, and the development of the winding structure to satisfy the mechanical characteristic are important tasks to realize an indirect cooling superconducting coil for a helical reactor.

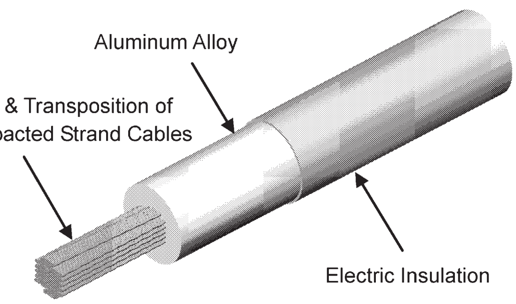

Fig. 1. Conceptual design of the indirect cooling conductor.

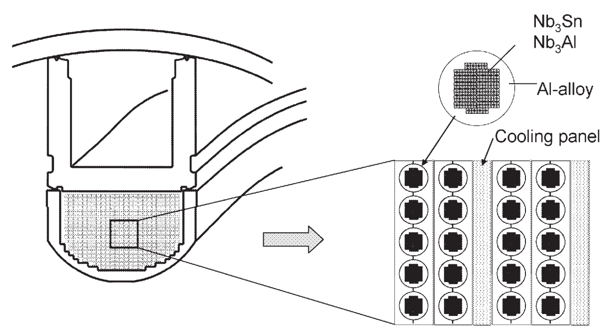

Fig. 2. Conceptual design of the indirect cooling coil.

References

1) Mito, T. et al., "Applied Superconductivity and Cryogenic Research Activities in NIFS", presented at ITC-15, Dec 6 – 9, 2006 and to be published on Fusion Engineering and Design.